

# **Light Curve Observations of Upper Stages in the Low Earth Orbit Environment**

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Active debris removal (ADR) is a potential means to remediate the orbital debris environment in low Earth orbit (LEO). Massive intact objects, including spent upper stages and retired payloads, with high collision probabilities have been suggested as potential targets for ADR. The challenges to remove such objects on a routine basis are truly monumental. A key piece of information needed for any ADR operations is the tumble motion of the targets. Rapid tumble motion (in excess of one degree per second) of a multiple-ton intact object could be a major problem for proximity and docking operations. Therefore, there is a need to characterize the general tumble motion of the potential ADR targets for future ADR planning.

The NASA Orbital Debris Program Office has initiated an effort to identify the global tumble behavior of potential ADR targets in LEO. The activities include optical light curve observations, imaging radar data collection, and laboratory light curve simulations and modeling. This paper provides a preliminary summary of light curve data of more than 100 upper stages collected by two telescope facilities in Colorado and New Mexico between 2011 and 2012. Analyses of the data and implications for the tumble motions of the objects are also discussed in the paper.

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